Low-Density, Microcellular Materials

Lightweight, structurally tailored cellular materials

Commercially available foams possess either low density or microcellular morphology, but not both. Low-density materials—plastic, "blown cell" foams—are used in polyurethane cushions and polystyrene cups. Microcellular materials are used in asymmetric membranes and filters. The commercial processes used to make these foams are limited by a tradeoff between density and cell size—they yield low density at the expense of cell size or small cell size at the expense of increased density. At LLNL, we have developed new methods for making low-density, microcellular materials (LDMMs) that combine both low density and small cell size and also meet requirements for composition, homogeneity, size, and strength.

Advanced synthesis techniques

We use several different synthesis techniques:

- Replication of sacrificial substrates
- Phase separation of polymer/solvent mixtures
- Polymerization of an inverse monomer emulsion
- Sol-gel technology.

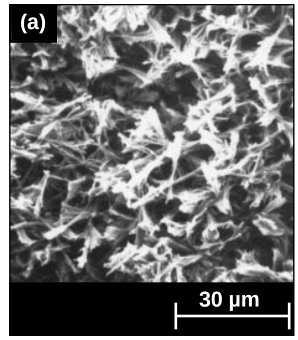
APPLICATIONS

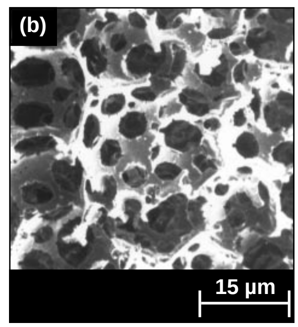
- *Sound barriers*
- *Thermal insulation*
- *Catalyst supports*
- *Porous electrodes*

In all cases, a solvent must be removed from the intermediate gel structure. Drying techniques include solvent evaporation, freeze-drying, and supercritical drying. Using each of these approaches, we have achieved LDMMs with densities ≤ 0.1 g/cc and cell sizes ≤ 25 µm. We have produced LDMMs from polymers such as cellulose acetate, polymethyl pentene (also known as TPX), polyacrylonitrile, agar, polyethylene, polystyrene, nylon-6, melamine-formaldehyde, resorcinol-formaldehyde, carbon, and silica.

We have created a biodegradable LDMM known as SEAgel, with densities as low as 0.003 g/cc (only 2× the density of air). We are investigating SEAgel as a new packing material, balsa-wood substitute, and time-release agent.

Aerogels, however, are the most interesting of all LDMMs. Their outstanding thermal, acoustic, optical, and electrical properties result from interconnected, nanometer-sized pores.





(a) Nylon-6 LDMM.
(b) Polystyrene LDMM.

Cell properties can be tailored

Cell size is intrinsically related to morphology, as are properties such as stiffness. LDMM morphologies range from reticulated, tetrahedral struts to interconnected webs and films. The overall morphology depends on the synthetic procedure and processing conditions.

We have studied the mechanical properties of LDMMs, both experimentally and theoretically. In general, LDMM morphologies are poorly connected and structurally inefficient. Both the strength and modulus show a stronger density dependence than is observed in most other open-cell foams, which have a scaling exponent of 2.0. We can, however, vary these mechanical properties by controlling the composition of the polymer and the processing technique.

Availability: LDMMs are available now. We are seeking industrial partners with whom we can collaborate on the scale-up and production of LDMMs for specialized applications.

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